Sol: Acid, clay, and water constant, acid variable.
Log (S:A) linear in log C, water constant.
Log (S:A) linear in log W, clay constant.

These three relations may be combined in

$$\text{Log } S = \log A + a \log C + b \log W + \text{const.}$$

With this as a guide the 27 analyses were written as 27 equations which were solved by least square methods to obtain values of the constants. Using natural logarithms the final relation is

$$\text{Log } S = \log A + 0.322 \log C - 0.318 \log W - 1.421$$

for grams of sol formed where pure halloysite is brought to equilibrum with dilute hydrochloric acid solutions at 96°. This relation holds for acid:clay ratios below 1:4 (by weight) up to about 4:1 above which free chlorides are formed. All constants depend upon temperature. The clay is in grams, the water in liters, and the acid in multiples of 0.75 gram. For $C=1=W$, $S=0.24$ A, or 75 $S=A$ in molar proportions, if the molecular weight of the sol is 510, indicating that the acid is used many times over. Water and clay are evidently in competition for the acid.

The chemical processes involved appear to be very simple. After the clay has adsorbed sufficient anions it is attacked by them. Free silica and chlorides go into solution and the chlorides are hydrolyzed, alumina combining with the silica to form a sol while the free acid returns to the clay to form more chloride. This process continues until the potential of the accumulated sol is balanced by that of the clay. This balance is at somewhat less than half the clay because the halloysite has some structural energy while the sol has little or none.

SUMMARY

Halloysite in warm dilute acid forms a sol having the composition of allophane $2Al_2O_3 \cdot 3SiO_2 \cdot 7H_2O$ after drying at 160° C., over an intermediate range of clay and acid concentrations.

A quantitative relation between sol formed and the acid, clay, and water used is obtained from experimental data covering the range from just sufficient acid to dissolve the alumina and water to dissolve the silica, to half and double these amounts.

At equilibrium, the clay solution contains free acid (pH 1.5 to 2.5) but no salt other than the sol in this range.

With clay and water as parameters, the amount of sol formed is in a fixed ratio to the acid present.

With acid and water as parameters, the sol varies with about the cube root of the clay present, indicating a reversible reaction.

The amount of sol varies inversely with the water present, clay and water competing for the acid present.

After oven drying at 160°, the sol (then gel) is soluble in hot water to the extent of about 0.3 gram per liter, slightly less than than silica gel, 0.4 gram per liter.

A general characteristic relation is deduced between amount of colloid formed and the amount of acid, clay, and water present. In reference 3, p. 45, it was shown that silica, alumina, acid, fluorides, and other salts added to the sol solution were without effect on the colloid formed. Variations with temperature and the nature of the acid remain to be investigated.

ECOLOGY.—*An analysis of the flora of the Bull Run Mountain region of Virginia using Raunkiaer's "life-form" method.*[1] H. A. ALLARD, Bureau of Plant Industry, Soils, and Agricultural Engineering.

INTRODUCTION

Ecologists have long been aware of the intimate relations between plant life and climate and, rightly regarding vegetation as an expression of the climatic complex, have attempted to devise methods to express this concretely and statistically in terms of plant life itself. Long ago Humboldt (*Physiognomik der Gewächse*, 1806) attempted to classify vegetation on something of an ecological basis. Griesbach (1872) and others building upon these concepts recognized

[1] Received November 6, 1943.

the intimate relation between the forms of plants and climate. Among these were Kerner (1863), Warming (1909), and Drude (1913). Such classifications as were recommended ignored taxonomic relationships since it is obvious that the ecological relations of plant life do not depend upon taxonomic concepts. Finally in 1908, a Dane, C. Raunkiaer, published a fundamental paper on life-forms and statistical methods.

Raunkiaer's method was unique in that it considered the plant to be a concrete, living expression not of one factor alone, but of the entire climatic complex, including temperature, humidity, and the water relations of the soil. The basis of his method, naturally, was the final adaptation of the plant, and the special feature selected by him related to the critical or unfavorable season, as indicted by the degree and kind of protection which enabled the plants to survive this in a particular region. This, it is obvious, was concerned mainly with the perennating buds, formed above or below ground in the case of perennials. While this concept does not afford a perfect measure of climate it has appealed to many plant ecologists as one of the best systems yet devised, since the plant itself has been chosen to represent its own success and survival in a given region.

LIFE-FORM SYSTEM OF RAUNKIAER

Raunkiaer in 1908 finally carefully selected and classified 400 representative plants from the world's flora, and used these to establish a provisional biological spectrum for the world, which he considered to be a standard for comparison. In 1916 he extended his studies to include the remaining 600 species, which he had originally chosen to represent his normal world spectrum. While there were only minor differences in the calculations for the two groups, Raunkiaer's spectrum based upon his final figures for 1,000 selected plants has been used in the present discussion.

His method requires a classification of all the Spermatophyta of a regional flora into five main groups, some of which are subdivided into smaller groups. These are listed as follows, with abbreviations:

Phanerophytes—Ph.—Branching woody plants, with their dormant buds wholly exposed to the air. These are further classified according to size into the following subgroups: (1) megaphanerophytes—Mg.—having a stature over 30 meters (98 feet); (2) mesophanerophytes—Ms.—with a stature of 8–30 meters (26 to 98 feet); (3) microphanerophytes—M.—2–8 meters tall (6–26 feet); nanerophytes—N.—under 2 meters tall ($6\frac{1}{2}$ feet).

Chamaephytes—Ch.—Plants with their dormant buds on the surface of the ground or just above it, not more than 25 cm. (10 inches). These are protected by snows in winter in colder regions, or by the plant remains in dry or warmer regions.

Hemicryptophytes—H.—Plants with their buds in the upper layer of the soil, near the surface, the aerial portions dying away in the unfavorable season further protecting these subterranean buds.

Cryptophytes.—Plants with their dormant structures entirely buried more or less deeply below the soil surface. This class has been subdivided as follows: Geophytes—G.—with bulbs tubers, rhizomes deep below the soil surface; Helophytes—Hl.—certain marsh plants growing chiefly in saturated soil or in water, from which the flower-bearing shoots emerge. Their buds are buried at the bottom of the water or in the muddy soil.

Hydrophytes—Hy.—Water plants with their perennating structures beneath the water.

Therophytes—Th.—Annuals living only for the season.

Classification of plants into these various groups requires a little care, for certain plants may seem to fall rather doubtfully into a given class. As a rule, however, it is not difficult to attain this objective, and a few doubtful cases change the final percentages very little. Some of the Hemicryptophytes and Cryptophytes have been less readily distinguished for this reason. Plants were considered to belong to the former class when their dormant buds were not deeper than 1 inch in the soil.

RELATIVE PROPORTIONS OF WOODY AND HERBACEOUS PLANTS IN DIFFERENT REGIONS

In temperate, humid regions the relative proportion of woody plants and herbs tends to be rather constant, as indicated by the following figures, which have been determined by Sinnott and Bailey (1914). Unfortunately these figures apply to the Dicotyledoneae alone, however. Inclusion of the Monocotyledoneae would decrease the proportion of woody plants and increase the proportion of herbs materially.

In the northern United States (Britton and Brown) woody plants constitute 22 percent of the Dicotyledoneae, and herbaceous 78 percent; northeastern United States (Gray), woody plants 23 percent, herbaceous 77 percent (Dicotyledoneae); including all Angiosperms in Gray's Manual (4,079 species), the figures become 14 percent woody, 85.9 percent herbaceous; Great Britain (Hooker), woody 11 percent, herbaceous 89 percent; Russian Empire (Ledebour), woody 14 percent, herbaceous 86 percent; France (Cusin and Ansberque), woody 11 percent, herbaceous 89 percent; Norway (Blytt), woody 14 percent, herbaceous 86 percent; Flora Orientalis (Boissier), woody 17 percent, herbaceous 83 percent; Spain (Lázaro é Ibiza) woody 21 percent, herbaceous 79 percent. All the above figures, unless otherwise stated, refer to the Dicotyledoneae alone.

Within the United States Deam (including all Spermatophyta) lists 2,568 species for Indiana, 14.4 percent being woody, 85.5 percent herbaceous. Ennis (1928) for Connecticut lists 1,453 native species, of which 15.06 percent are woody and 84.9 percent herbaceous. In the relatively very small Bull Run area (including all Spermatophyta) 18.2 percent are woody, 81.8 percent herbaceous.

It is well known that the percentage of woody plants, trees and shrubs in humid regions increases as one approaches the warmer tropical latitudes. These relations are clearly shown in the following figures based upon the Dicotyledoneae alone: Florida Keys (Small), 46 percent are woody plants, 54 percent herbaceous; Japan (Matsumura), 43 percent woody, 57 percent herbaceous; Brazil (Mueller), 74 percent woody, 26 percent herbaceous; Amazon Valley only, 88 percent woody, 12 percent herbaceous; Malay Peninsula (King), 83 percent woody, 17 percent herbaceous; Philippines (Merrill), 68 percent woody, 32 percent herbaceous; Dutch East Indies (Koorders), 75 percent woody, 25 percent herbaceous.

Comparisons of these figures especially for the humid, temperate regions favorable to forest indicate the common pattern of the vegetation in its ecological aspects. This is true whether one considers the relatively small Bull Run area, the State of Indiana, large portions of the United States (Gray, etc.), Great Britain, or Italy. If the floristics of the primeval vegetation which formerly existed in all these regions could be known it is probable that even greater uniformity of ecological structure would be established. These uniformities appear to represent fundamental floristic and structural relations of the vegetation for the countries in question. However, if plant life, as it now exists, and as Raunkiaer has assumed, is a dependable, concrete measure of the climatic complex, such fundamental relations should obtain. There are probably greater differences existent in the species composition of the vegetation of the several regional floras mentioned than in the life-forms that make up ecological structure of these.

BIOLOGICAL SPECTRUM OF THE FLORA OF BULL RUN MOUNTAIN

A comparison of the biological spectrum of the Bull Run area with Raunkiaer's normal spectrum is presented in Table 1. The data for the Bull Run area are based mainly upon the list of plants recently reported upon by Allard and Leonard (1943). In this paper 1,010 different plants were recognized, 8 other plants (not yet added in print) being found in 1943, bringing the total to 1,018 plants.

The data of Table 1, all of which refer to the Bull Run area aside from Raunkiaer's spectrum, are of some interest. Some workers have been careful to make use of only the native Spermatophyta in the calculation of a biological spectrum for their region. A comparison of the spectra for all the native and introduced Spermatophyta and for the native Spermatophyta alone reveals striking agreement, however. The data for the native Dicotyledoneae alone also show only slight departure from these values.

TABLE 1.—PERCENTAGE OCCURRENCE OF LIFE-FORMS IN THE NORMAL SPECTRUM OF RAUNKIAER AND THE VEGETATION OF THE BULL RUN REGION

Spectrum	Total flora	Occurrence (percent)									
		Th	Ch	H	G	Mg	Ms	M	N	Hl	Hy
Raunkiaer's normal	1000	13	9	26	4		8[1]	18	15		2[2]
All Spermatophyta, native and introduced	980	17.0	1.4	51.7	9.1	1.8	6.4	5.6	4.4	1.4	.8
All native Spermatophyta	847	15.1	1.6	50.4	9.8	1.8	6.3	5.5	4.7	1.6	.8
All native Dicotyledoneae	616	15.9	2.2	48.3	7.3	2.6	8.7	7.1	6.4	.4	.6
All native Monocotyledoneae	224	13.4	—	62.0	16.9	—	—	1.3	—	4.8	1.3
All introduced Dicotyledoneae	108	32.4	—	50.9	.9	—	5.5	5.5	3.7	1.4	.8
All introduced Monocotyledoneae	25	16.0	—	60.0	24.0	—	—	—	—	—	—
All native Spermatophyta in primitive wooded areas	446	3.3	1.3	52.9	12.1	4.0	10.4	8.0	4.9	1.7	.8
All native Spermatophyta in fields, pastures, or cleared or cultivated areas	402	28.1	1.9	50.0	7.2	—	2.4	3.4	4.4	—	2.2

[1] Mg + Ms.
[2] Hl + Hy.

Comparison with Raunkiaer's normal spectrum reveals certain departures for some classes. Considering all native and introduced Spermatophyta, the greatest departure is shown for the Hemicryptophytes (H), which in the Bull Run flora have been determined to be 51.7 percent as compared with the normal spectrum of 26 percent. Since depth of the dormant buds serves to distinguish the Hemicryptophytes from the terrestrial Cryptophytes (G), one may expect some degree of error to appear here in deciding into which class a certain plant should fall. If, however, a summation of the Hemicryptophytes (H) and Cryptophytes (G) is made (the number of Helophytes (Hl) and Hydrophytes (Hy) is too small to affect the results materially), one obtains 30 percent for the normal spectrum and 60.8 percent for the Bull Run spectrum. These striking differences indicate a climate in the Bull Run area highly favorable to Hemicryptophytes and Cryptophytes, plants that are adapted to withstand a cold, dormant season of considerable severity such as the higher temperate latitudes experience.

The biological spectrum for all introduced Dicotyledoneae of Bull Run Mountain agrees closely with that shown for all the Spermatophyta of the area, except in the proportion of Therophytes (T) representing the annuals. This has increased from 17 percent for the latter to 32.4 percent for the former. Since field conditions offer a more favorable habitat for this class, as most introduced plants cannot compete with the vegetation of forest areas, this relationship is the natural one.

The spectra of all native Spermatophyta found in wooded, primitive areas, and also in fields, pastures, or cleared and cultivated areas has also been presented. The differences shown in some of these groups are of significance. It will be noted that the annuals or Therophytes (T) in the more primitive woodland areas represent only 3 percent of the plants, while in cleared and cultivated areas the figure has become 28.1 percent. Hemicryptophytes (H) and Cryptophytes (G) in the more stabilized woodland make up 65 percent of the flora, and only 57.2 percent in the cleared areas. Since there is a progression from annual to perennial types in the early successional stages, and the climate favors an abundant hemicryptophytic and cryptophytic element, an increase in this class of plants is a natural condition as woodland prevails. The herbaceous element in the woodland areas is 72.1 percent, and 89.4 percent in the cleared areas. This too is a correct reflection of actual differences in the vegetation in the two habitats, since the herbaceous element is predominant in the early stages of succession where the forest has been entirely destroyed. The woody element of the cleared areas is only 10.2 percent, compared with 27.3 percent in the more natural woodland areas. Immediately following abandonment from cultivation, the woody element may be almost entirely lacking, but various weedy trees and a variety of shrubs make their appearance in older fields and pastures until a closed overstory of trees has captured the area. The statistical differences in the life-forms of the two areas plainly emphasize the pioneer successional nature of the old field assemblage in its trend toward woodland. If the field and pasture areas were selected on the basis of age from time of abandonment, the woody element would be found to increase with corresponding decrease in the herbaceous element until the stability of climax conditions between trees and herbs had been attained.

SIMILARITY IN THE SPECTRUM OF THE FLORA OF BULL RUN MOUNTAIN AND THAT OF SOME OTHER EASTERN AREAS

Summarizing the woody elements as represented by Mg, Ms, M, and N, we have 41 percent for the normal spectrum, 18.2 percent for all Bull Run Spermatophyta, and 15.1 percent for all native Spermatophyta of the Bull Run area. If one considers the average for the Dicotyledoneae as listed in the floras of Gray, and Britton and Brown, for the northern and northeastern United States, Small's southeastern flora, Chapman's southern flora, Coulter for the Rocky Mountains, together with the floras of Great Britain, France, Germany, Switzerland, the Russian Empire, Norway, Spain, Syria and the Orient, the woody element amounts to 17.4 percent, and the herbaceous element 82.6 percent. For the Bull Run region the woody element becomes 18.2 percent and the herbaceous becomes 81.9 percent for all native and introduced Spermatophyta. The woody and herbaceous elements of the native and introduced Dicotyledoneae of the Bull Run Mountain area amount of 24.3 percent and 75.7 percent, respectively. The latter figure for the herbaceous element occurring in the Bull Run Mountain area is much higher than 54 percent which has been taken to represent the herbaceous element for the normal spectrum of the world flora. This figure for the herbaceous element falls below that of any temperate region of North America, Europe, or Asia. It very closely approaches the dicotyledonous herbaceous element of floras found in warm areas; namely, 54 percent for the Florida Keys (Small), 57 percent for Japan (Matsumura), and 54 percent for the Upper Gangetic Plain (Duthie), where the phanerophytic or woody component is high. The high herbaceous element occurring in the Bull Run Mountain area indicates a regime of north temperate climate considerably removed from that of warm, humid latitudes.

Taylor (1915) (1918) determined the growth forms for the vegetation of New York City and vicinity, and the total flora of Long Island, N. Y., on the basis of Raunkiaer's concepts. Ennis (1928) did a similar and very excellent piece of work for Connecticut. This work is of particular interest when compared with the percentage composition of the growth forms of all Spermatophyta of the Bull Run area, owing to the close agreement in the two areas as shown by the data in Table 2.

TABLE 2.—PERCENTAGE OCCURRENCE OF LIFE-FORMS IN THE SPERMATOPHYTA FLORA OF THE VICINITY OF NEW YORK CITY; OF LONG ISLAND, N. Y.; CONNECTICUT; THE BULL RUN AREA; INDIANA; AND THE NORTHERN AND EASTERN UNITED STATES (Gray)

Spectrum	Total flora	Occurrence (percent)								
		Th	Ch	H	G	Mg	Ms	M	N	Hl+Hy
Vicinity of New York City (native flora)	1907	13.0	5.29	33.29	20.23	.52	4.03	7.18	3.51	11.74
Long Island	719	13.94	5.89	33.15	20.1	.89	4.37	6.34	2.77	10.9
Connecticut (native)	1453	11.7	1.9	49.4	13.2	1.5	3.9	5.8	3.7	8.5
Bull Run region	980	17.0	1.4	51.7	9.1	1.8	6.4	5.6	4.4	2.2
Indiana (Deam)	2420	11.2	1.4	50.9	11.6	1.5	5.08	4.5	3.1	5.7
Gray's Manual (N. & E. U.S.)	4283	15.2	1.4	52.4	10.4	.9	4.1	4.6	4.9	5.6

Total Hemicryptophytes and Cryptophytes (H, G, Hl, Hy). New York City 65.36 percent; Long Island 64.5 percent; Connecticut 71.1 percent; Bull Run 62.0 percent; Indiana 68.4 percent; northern and eastern U. S. (Gray) 68.5 percent.

Woody plants (Mg, Ms, M, N). New York City 15.24 percent; Long Island 14.37 percent; Connecticut 14.9 percent; Bull Run 18.2 percent; Indiana 14.7 percent; northern and eastern U. S. (Gray) 14.7 percent.

Herbaceous plants (Th, Ch, H, G, Hl, Hy). New York City 83.55 percent; Long Island 85.63 percent; Connecticut 84.7 percent; Bull Run 81.8 percent; Indiana 85.3 percent; northern and eastern U. S. (Gray)85.3 percent.

The greatest discrepancies are shown for the Hemicryptophytes (H) and the Cryptophytes (G, Hl, Hy). However, these classes are most readily confused, since little more distinguishes the plants of each than the depth of the dormant buds. It will be noted that the summations, however, give remarkably close total percentages. The summations of all the Phanerophytes or woody plants (Mg, Ms, M, N), and the herbaceous plants (T, Ch, H, G, Hl, Hy) also give very close values. These results indicate that the ecological structure of the vegetation in these four areas is strikingly similar.

PHYSIOGNOMY OF VEGETATION NOT REVEALED BY THE BIOLOGICAL SPECTRUM

Raunkiaer's biological spectrum was devised to serve as a concrete expression of climate in terms of living plants. This has required a reduction of all the climates of the world to an average expression in terms of growth forms, in order that the spectrum would represent a mean concrete expression of the plant life of temperate, cold, and tropical climates. Since very cold and very warm climates have helped to make up this normal spectrum, it must represent some intermediate condition of climatic plant expression so that it can be neither strictly tropical, temperate, nor frigid. It would be exceptional, then, to find a section of our north temperate flora, a frigid or a tropical flora showing exact agreement with this standard spectrum in all respects.

While the Raunkiaer method of analyzing vegetation on the basis of its ecological life-forms may afford a statistical means of evaluating the structure of vegetation of a climatic zone, it does not reveal the physiognomy or visual aspect of such vegetation. It does not indicate whether the dominant vegetation of the climax forest is deciduous, evergreen, coniferous, or broad-leaved evergreen. As Ennis has shown in her discussion of Connecticut spectra, the Coastal Plain areas of the South have the physiognomy, visually, of a coniferous forest due to an overstory of these, but the region is one of deciduous forest in its fundamental trends. In other words, the coniferous aspect is due to other influences than climate, such as determines the great natural coniferous forests of the North, and the higher mountain lands of the Appalachians. These forests at all levels are coniferous in their structure. In the Bull Run area, the deeper, richer soils of the slopes and valleys are given to deciduous forest naturally. The sharp, dry, barren ridge crests carry a permanent thin mantle of several species of pines, which, in some areas noticeably affect the physiognomy of the area.

There is but one broad-leaved evergreen species in the Bull Run area which has any physiognomic significance, and this is confined to the understory entirely. This shrub, *Kalmia latifolia*, completely dominates the understory of extensive areas of the woodland slopes to such an extent that little else can compete with its dense vegetation. In reality this evergreen shrub is the only species normal to the flora of the Bull Run highlands, for *Ilex opaca* and *Phoradendron flavescens* are practically out of their normal range here. Only 10 species of woody evergreen plants occur in this area.

The minor importance of this group in this area compared with the flora of various other areas is shown in Table 3.

Table 3.—Percent of Woody Evergreen Species, Broad-Leaved Evergreen Species, and Evergreen Conifers in the Flora. (Data in part from Ennis, 1928.)

Flora	Species of woody plants	Evergreen species		Broad-leaved evergreens		Evergreen conifers	
		No.	Percent	No.	Percent	No.	Percent
Florida	357	111	31	98	27.4	13	3.6
District of Columbia	187	20	10.5	12	6.3	8	4.2
Connecticut	219	21	10	8	4	13	6
Penobscot Bay	97	16	16.4	4	4.1	12	12.3
Bull Run region	188	10	1	3	1.5	7	3.7

The data of Table 3 indicate the increased importance of the broad-leaved evergreen plants in Florida, and the minor importance of the evergreen conifers here. This relation is reversed for the Penobscot Bay region where the evergreen conifers become a dominant element of the flora and the broad-leaved evergreens reduced. Although the woody plants of the District of Columbia and the Bull Run area are almost identical in number, with a similar evergreen coniferous content, the broad-leaved evergreens are much more important in the former area.

ADAPTATION OF LIFE-FORMS OF PLANTS IN RELATION TO THE UNFAVORABLE SEASON

While Raunkiaer's classification takes into consideration the adaptation of the various plants to the season most unfavorable to growth, this being the severe winter season in the colder northern latitudes, the relationship is not one of direct cause and effect. As a matter of fact in the case of most of the woody and herbaceous perennials the perennating buds are laid down near midsummer in response to factors of the climate seasonally far removed from the actual cold of wintertime. Whatever these factors may be it is obvious that the plants have been ecologically preconditioned in one way or another to meet the oncoming severe winter conditions at the end of the warm growing season, even though this may have been merely an incidental and not a causal relationship in the life of the plant.

While the factors of humidity, temperature, wind velocity, rainfall, and percentage of sunshine are seasonally extremely variable, one factor, length of day, is an astronomical event recurring with great constancy from year to year. The work of Garner and Allard in 1920 demonstrated that the life-form and life-duration of plants could be profoundly modified by this regular recurring seasonal factor of climate. At the present time the great desideratum in our knowledge of climate in relation to the life-forms of plants is the lack of specific information as to how the climatic complex selectively or adaptively determines the character of the spectrum that will prevail in a particular zone. That there is a fundamental reason why Hemicryptophytes and Cryptophytes are dominant in the flora of the cooler middle latitudes, such as in our humid north temperate zone, cannot be doubted. It cannot be denied that a given flora is adaptively related to a particular climate as Raunkiaer's life-form studies have postulated. Unfortunately, there is little evidence at hand at the present time to explain the mechanism of this seeming adaptiveness. Raunkiaer, as the result of

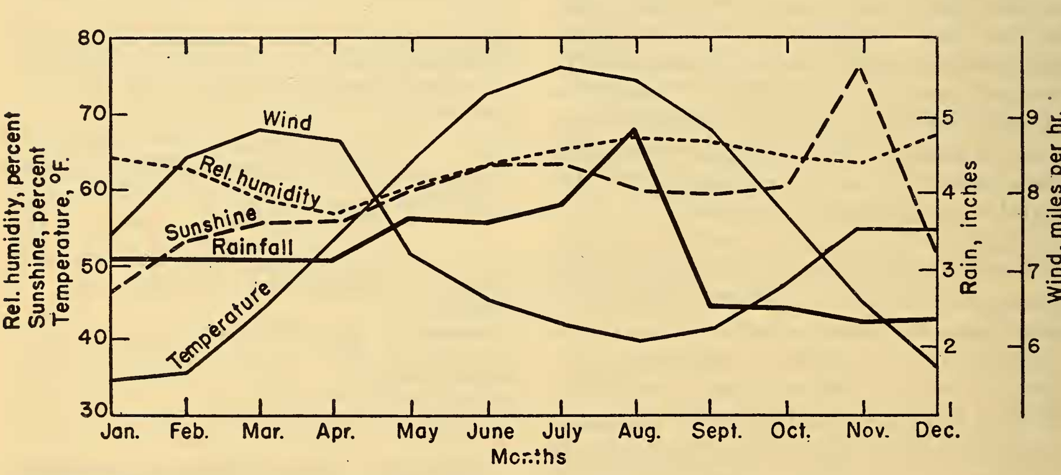

Fig. 1.—Climatic regime for the Bull Run Mountain region, typical of the Hemicryptophyte climate of the Eastern Atlantic States. The normal temperature, humidity, sunshine percentage, wind velocity, and rainfall curves are shown for each month of the year. Rainfall is for nearby Manassas, Va., interpolated for 35 years from about 20 years of records. The temperature curve is the mean of records for Washington, D. C., and Culpeper, Va., which is the nearest weather station recording temperatures. The curves for humidity, wind velocity and sunshine were taken from Washington records. The humidity curve is based upon the mean of the normal minimum and maximum values computed from records of the U. S. Weather Bureau station for 7:30 A. M. and midday, respectively. The figures for temperature also correctly represent the percentages of sunshine and relative humidity.

his fundamental investigations of the life-forms of plants showed that some species can change their characteristic life-form to a greater or less degree. One of these, *Tussilago farfara*, in Denmark is a Cryptophyte, but in milder or more southern latitudes becomes a Hemicryptophyte. This observation has fundamental implications in an interpretation of the dependence and occurrence of life-forms in relation to a particular climate.

CONCLUSIONS

It is obvious that the Bull Run region, like all the eastern portions of the United States, is dominated by a Hemicryptophyte climate. Fig. 1 shows the dominant features of such a climatic regime with respect to normal temperature, relative humidity, rainfall and wind velocity over a long period. Temperature and available moisture are very largely responsible for the general character of the climax forest vegetation of a region. It appears from Fig. 1 that every factor of the climatic complex in our eastern forested region favors the conservation of moisture during the growing season so far as plant life is concerned. As the duration and percentage of sunshine and temperature increase the relative humidity of the air and the rainfall increase, and the mean wind velocity decreases, serving as an additional check upon evaporation at a time when the temperatures are highest. It is thus seen that when the plants are forced into their maximum activity by one set of factors, others operate to counteract any unfavorable tendencies, thus constituting one of the most ideal climates for many types of mesophytic vegetation. This favorable and supplementing interplay of all factors, then, is particularly favorable to a very luxuriant summer vegetation dominated by deciduous forest as the overstory, with a rich Hemicryptophyte flora beneath this forest cover capable of surviving severe conditions, with its enforced dormancy of vegetative activity.

Whatever the significance of Raunkiaer's normal world spectrum, his studies indicate convincingly that the life-forms of plants are so definitely related to a particular climate that the constancy of relationship must be determined or conditioned by the operation of definite climatic laws prevailing under every climatic regime. It must be admitted, also, that his life-form classification, with its statistical aspects, may have genuine ecological meaning in the interpretation of some features of the striking relationships of vegetation everywhere.

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